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The object of this report is to document the at sea test performed on six over-the-side expendable optical profilers (XKT's). A substantial portion of this report has been derived from Sippican report R-2545.

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WATER DEPLOYMENT TEST REPORT

AXKT

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1.0 OBJECTIVES

The object of this report is to document the at sea test performed on six over-the-side expendable optical profilers (XKT's). A substantial portion of this report has been derived from Sippican report R-2545.

2.0 DESCRIPTION of TEST

This test is the first functional test of the new designed Air-Launchable Expendable Optical Profiler (AXKT). The test consists of deploying six AXKT's off a surface ship deck and recording the resulting signal as the probe descends through approximately 200 meters of water. The received data is then decoded and analysed for the purpose of determining the nominal operating limits of the system.

An analog tape recording of the received signal was made in the event of a computer/software failure. This recording was done on a Marantz cassette recorder with the analog signal being recorded on one channel and a verbal log on the second channel. The quality of this recording is sufficient to be able to recreate a probe drop and recover any data that was lost due to deck gear failure or software problem.

The units were deployed approximately 5 miles east of Provincetown, MA. in water 175 meters deep. This water was judged to be of sufficient depth as to allow the units to exercise their full 6 decades of dynamic range from previous site observations.

3.0 PURPOSE of TEST

The purpose of this test is to verify the operation and functionality of the system without subjecting the unit to the extremes of an air launched environment.

Several parameters of the system were verified in the test that could not be accurately or easily duplicated in a laboratory environment. In particular, the operation of the unit when exposed to varying light levels over more than five decades of range, and the level of signal to noise when the system is operating in its full configuration (Operational probe, full BT wire link, RF transmitter and acquisition equipment).

The test also allows testing of process control as inter-probe repeatability was measured as well as the number of catastrophic failures due to water leaks, BT wire breakage or any number of other potential failure modes.

4.0 TEST ITEM CONFIGURATION

Seven units were built for this test. All units had hand built PCBs incorporated into either modified XCP parts or parts specifically designed and built for the XKT unit. The system did not include the hardware necessary to support an air drop. These items include the outer skin that would protect the buoy/probe system in the air chute, parachute and decelerator housing. The remainder of the system, (buoy and float), in every other way, reflected the configuration that will be used in a full up air deployable unit.

All seven units were tuned to transmit on channel 12, and were hand tested after assembly. One unit was 'deployed' at Sippican in a test pool to verify proper squib and transmitter operation. The unit was allowed to transmit 'data' for a duration equivalent to that of a normal drop and at the conclusion, the scuttling mechanism was observed for proper operation. This unit performed properly in all respects and the remaining six units were then packed in plastic ship launched containers (SLCs) for at-sea testing.

5.0 AT-SEA Testing

The test site was located approximately 5 miles east of Provincetown, MA. with a water depth of 175 meters. The air temperature of the test was 35 degree F, with sky conditions being clear for the first two units and then rapidly becoming overcast as the afternoon progressed. The sun was located at an azimuth of approximately 45 degrees at the start of the first unit with the full test taking approximately one hour. High winds had prevailed during the past three weeks mixing the water to the point where there were very few features, either thermal or optical, to be found. As a result of this, the stability of the optical and temperature signal could be evaluated to some degree.

The units were deployed at 10 minute intervals beginning at 12:20pm. Each unit was given a predeployment test to verify battery strength and deck gear receiver operation. This test consists of supplying power from an external power supply to the float housing and verifying certain signals or 'tones' could be heard on the receiver. This test verifies that transmitter, BT wire, and probe are all somewhat functional and that continuity through the receiver and deck gear is present. Upon successful completion of the prelaunch test, the units were deployed on the sunlit side of the ship with the ship motoring far enough to avoid causing ship reflections/shadows. For each deployment, the unit was observed to enter the water and the length of time required to resurface was noted. In all cases the units resurfaced within 3 seconds.

Once the float was noted to be at the surface, the acquisition software was activated and analog recording system started. The actual acquisition of data occurs automatically once data transmission commences. The time between float activation and the presence of transmitted data was noted to ensure that all units underwent a 30 +/-5 second stabilization period.

The depth of the water (175 meters) allowed the units to impact the bottom before BT wire had completely payed out (Total length of BT wire = 250 meters). It was noted at this depth, available light levels had reached below specified limits. At this low light level, the optical signal began to show signs of instability and nonlinearity.

Bottom impact could be seen on the plotted data traces as the temperature signal 'spiked' and then showed the characteristic trend of self heating.

The floatation part of the buoy was then recovered immediately on four units and the float scuttle mechanism disabled. The last two units were allowed to begin scuttling before recovery to verify the operation of the scuttle timing circuitry.

The environmental conditions were such that the first unit experienced full sunlight at the surface while the remaining units experienced varying degrees of overcast at the surface.

6.0 DATA REDUCTION

The at-sea data acquisition software stores the data as actual frequencies that are measured from the data stream. In this way, the raw data is always available for various uses. For the purpose of this test. This data was uploaded to a VAX780 for final data reduction. The algorithms used are essentially the same as those used in the real time PC based system but additional 'quality of data' checks are incorporated into the VAX software for additional information. The algorithms used for this reduction can be found in appendix A.

7.0 DISCUSSION of RESULTS

The following is a discussion of the results of the six test units. The actual traces for the units can be found in appendix B.

7.1 General Observations

The operation of this system appears to be viable at least in a over the side environment. All six units performed to some degree without experiencing catastrophic failure or gross measurement errors. All units performed within spec for timing of deployment and (for those tested) scuttling operation. All units transmitted optical data that extended over a five decade dynamic range and optical/temperature data to depth (175 meters).

Intercomparisons among the various units appears reasonably consistent. As no standard was used in this test, the only parameter of operation is how consistent the data is from unit to unit. The temperature data showed very good agreement between the units with one unit (#6) showing an offset of approximately 0.5 degrees C. The optical data between units showed more variability with the data sets seemingly falling into two groups. The first two units deployed show a higher 'K' average than the last four units. This could be as a result of ship drift moving into a region of higher particulate concentration or the fact that the first two units experienced a much more cloud free sun than the last four resulting in a more specular light source.

All units showed a characteristic 'bump' right at the very beginning of deployment. This is due to the shadowing effect of the float housing at the very surface but very quickly is negligible as the viewed ocean surface increases. All units also showed an increase of optical attenuation levels just before the bottom. This is presumably due to bottom sedimentation being stirred up by local currents.

7.2 Individual Observations

Unit # 5 was the first unit deployed. This unit was deployed with full sun at approximately 45 degrees off the horizon. As can be seen from the trace, the optical signal has been 'clamped' at a level just under $10E8$ picoamperes. This clamping occurred in the MK9 (deck gear) signal acquisition equipment due to improper scaling in the processor's firmware. At approximately ten meters, the light level had dropped to a level that was translated properly. A signal dropout occurred on the temperature trace at 22 meters for a period of one data point. The same thing happened on the optical trace at a depth of 122 meters. The dropout represents less than 0.08% data loss for the entire drop. The resulting calculation of K exaggerates this loss due to the algorithm for the calculation which uses a series of points to determine K (See appendix A).

As a result of the higher initial light level, the received signal remains at a reasonable level when sea floor impact took place (The depth of the water for this unit was greater than 180 meters so no change can be seen on the trace).

Unit #6 exhibits the greatest noise level of all six units. As can be seen, the initial light level is considerably less than unit #5, resulting in no noticeable limiting. The received optical signal does show considerable instability throughout the drop, particularly during the first 15 meters of data. Having a lower initial light level, the device received less than the specified $10E2$ picoamperes (Max I = $10E8$ pA minus six decades of resolution), and the calculation of K was ceased at this point.

The temperature as determined by the probe shows an offset of about -0.5 C relative to the other five units. This error is most likely a factory calibration error of the temperature circuit as the signal appears to be quite stable over the drop.

The depth of the water for unit #6 decreased to the point that bottom impact can be seen at 178 meters.

The remaining units (#7-10) performed quite consistently among themselves. All had the same relative initial light levels and all showed good agreement for the K through the water column. Bottom impact occurs at around 175 meters for the four units with increasing attenuation the last 20 meters before impact. The peak to peak K variation for these four units appears to be less than .005 although as there is no reference data to compare to, this number could change substantially.

The units appear to have performed quite well. All four units measured approximately the same 'K' value and temperature looks good.

The well mixed water eliminated most of the interesting features, however near the bottom, the K value appears to rise substantially, presumably due to suspended sediment churned up from the bottom. The impact to the floor can be detected by the loss of the temperature data, at an approximate depth of 175-180 meters.

8.0 CONCLUSION

Six XKT test units were deployed in 175 meters of water on Provincetown, MA. All six units fell to depth returning data to depth with all showing substantially the same data relative to one another. The first two units experienced full sun/bright overcast, with the remaining four units seeing varying degrees of overcast.

Unit number 5 showed optical saturation immediately at the surface due to a scaling error in the acquisition gear. Unit number 6 showed an increase in noise level for the optical data producing an 'K' scatter greater than the targeted specifications (0.01). The same unit also showed a temperature offset of approximately 0.5 degrees C, presumably due to a calibration error.

The remaining units produced good data in that calculated results were consistent among the different units and that there was no fallout of data for the duration of the drop.

The results of this test indicate the the operation of the XKT is workable and has proved to be a reliable platform (For ship launched operations) for gathering optical data in the blue-green region. The results of this test will allow more definitive system specifications to be established for future testing.

APPENDIX A

Frequency to Engineering Units:

Temperature

$$R_{th} = \frac{1}{(4.4)(2490E-12)(TFRQ)} - 30900$$

$$Temp (K) = \frac{1}{A + (B) \ln(R_{th}) + (C)(\ln(R_{th}))^3}$$

Where

Rth is thermistor resistance

TFRQ corresponds to the frequency of the temperature signal

A, B, and C are coefficients that are specific to the thermistor

Optical

$$I_o = \frac{15.68 - (.046)(OFRQ)}{2.3}$$

$$K = \frac{SLOPE}{D2 - D1}$$

Where

OFRO is the frequency corresponding to the optical signal

I_o is the optical irradiance on the sensor

D_2, D_1 is the depths of two adjacent sampling points

SLOPE is the slope of the optical irradiance. In this test, the slope was calculated by doing a least squares fit of a line through 10 data points (5 points before the current point and five points after).

Note: The computation of 'K' was performed only as long as the absolute irradiance level remained above the low level cutoff point. In this case, this value corresponded to 60 db below the irradiance corresponding to $1E8$ picoamperes or $1E2$ picoamperes.

APPENDIX B

XKT Data Traces

Notes:

- 1) The following graphs represent the data recovered from the sea test.
- 2) The data is represented as a display of three parameters versus depth. The trace marked T is the temperature profile in degrees C.

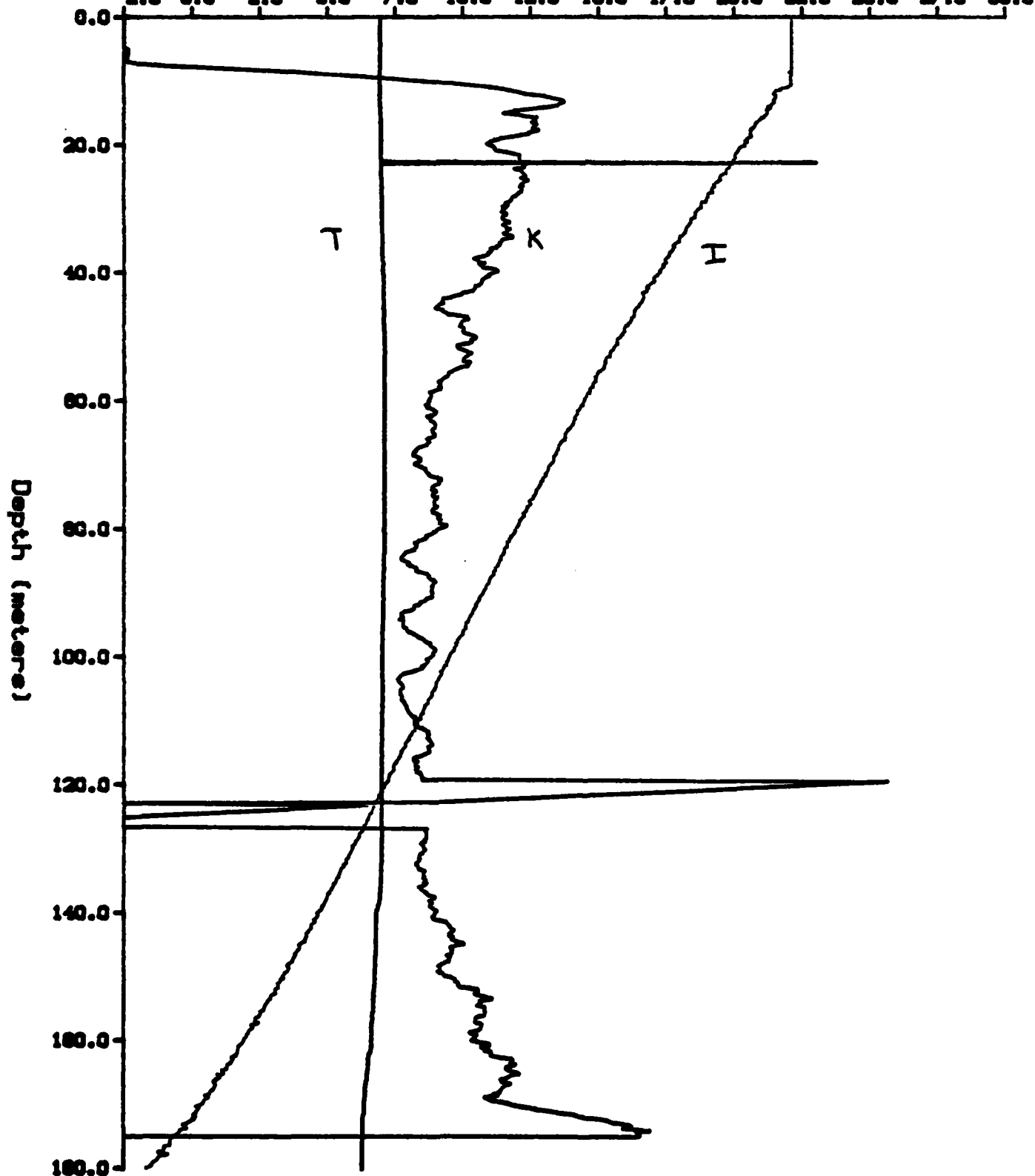
The trace marked with a I represents the log (base 10) of the optical detector current in picoamperes, i.e., '7' on the scale corresponds to 10^7 picoamperes.

The trace marked with a K is the extinction coefficient in units of $1/M$.

- 3) The calculation of K is terminated when the detector is below its detection threshold (10^2 picoamperes).

K 1/m
 0.00 0.01 0.02 0.03 0.04 0.05 0.06 0.07 0.08 0.09 0.10
 Irradiance (log I)
 1.0 2.0 3.0 4.0 5.0 6.0 7.0 8.0 9.0 10.0

Temp. C
 -2.5 0.0 2.5 5.0 7.5 10.0 12.5 15.0 17.5 20.0 22.5 25.0 27.5 30.0

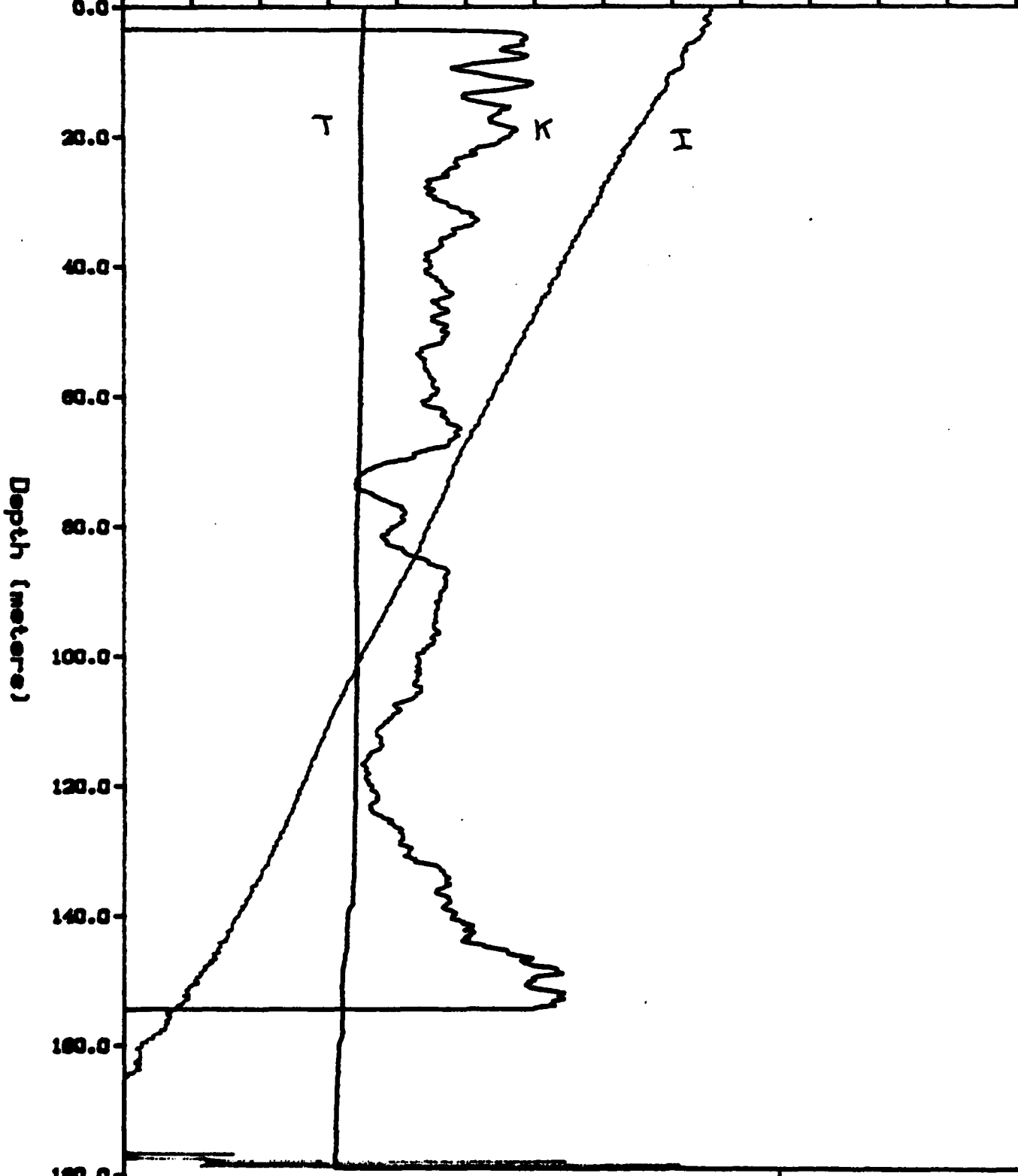


DATE: 1/2/90
 FILE: S.TIK

5 XKT

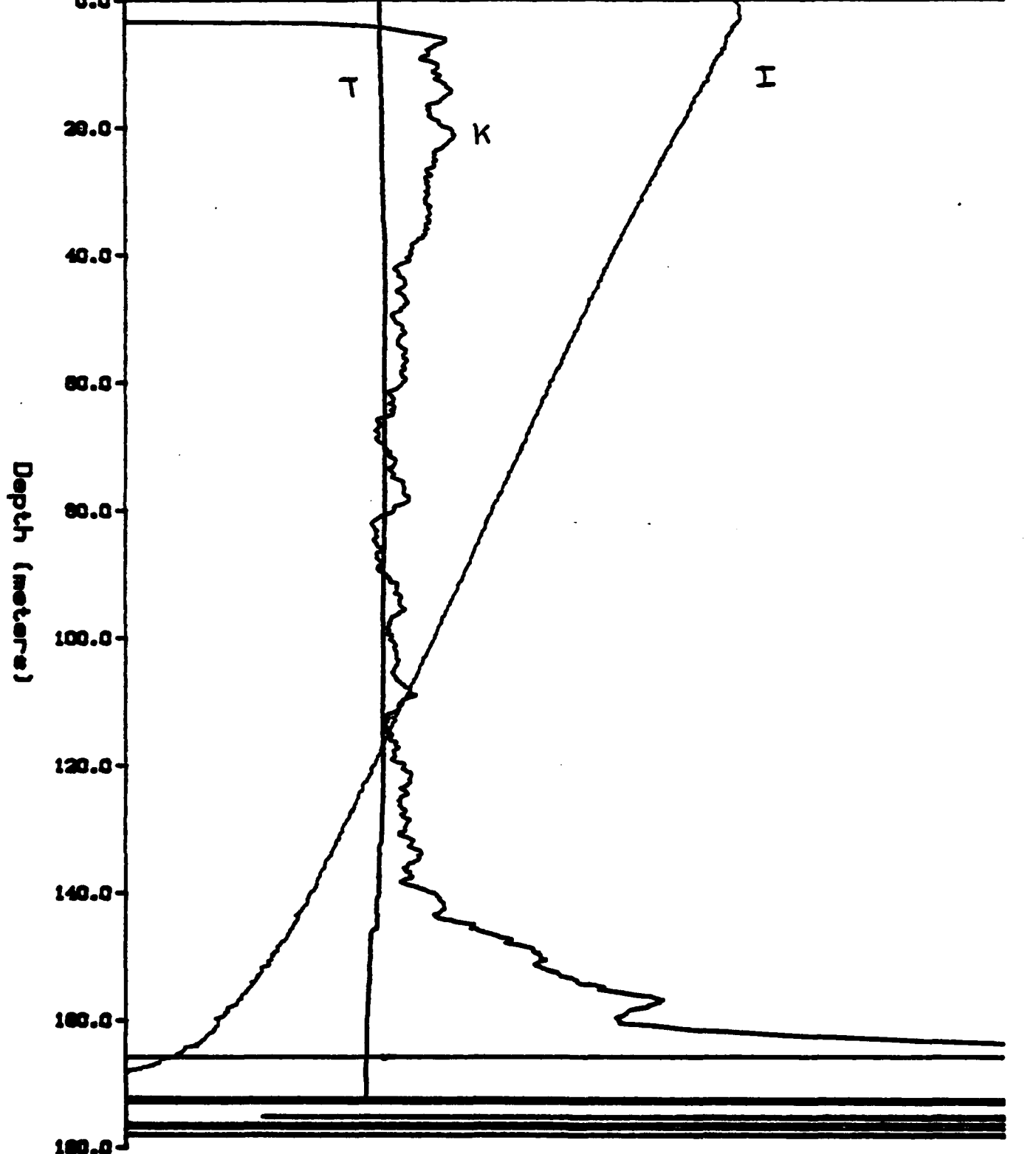
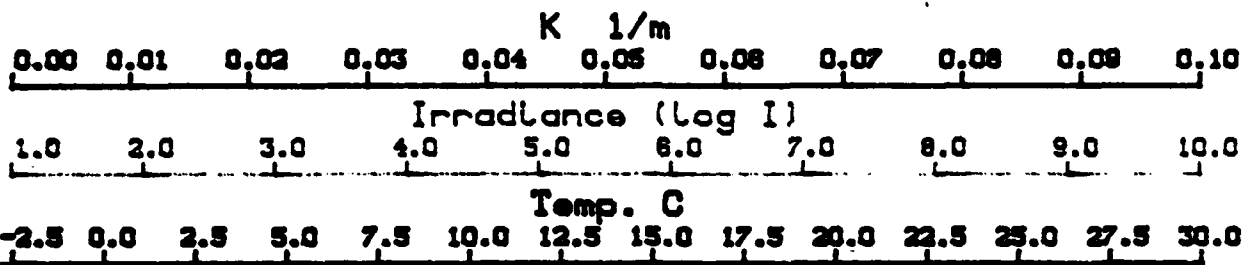
K 1/m
0.00 0.01 0.02 0.03 0.04 0.05 0.06 0.07 0.08 0.09 0.10
Irradiance (log I)
1.0 2.0 3.0 4.0 5.0 6.0 7.0 8.0 9.0 10.0

Temp. C
-2.5 0.0 2.5 5.0 7.5 10.0 12.5 15.0 17.5 20.0 22.5 25.0 27.5 30.0



DATE: 1/2/90
FILE: 6.TIK

6 XKT



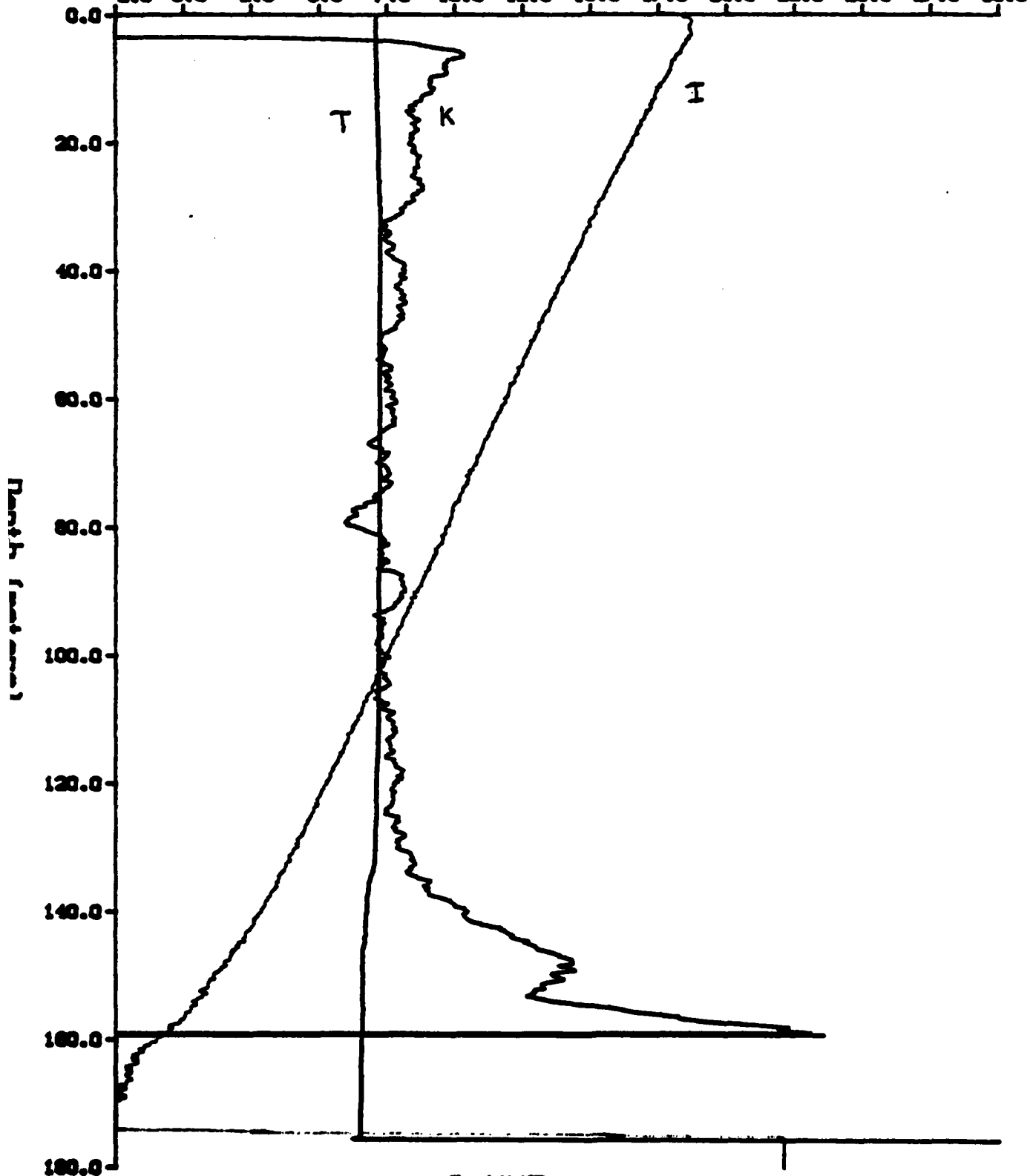
DATE: 1/2/90
FILE: 7.TIK

#7 XKT

0.00 0.01 0.02 0.03 0.04 0.05 0.06 0.07 0.08 0.09 0.10
 K 1/m
 Irradiance (log I)
 1.0 2.0 3.0 4.0 5.0 6.0 7.0 8.0 9.0 10.0

Temp. C

-2.5 0.0 2.5 5.0 7.5 10.0 12.5 15.0 17.5 20.0 22.5 25.0 27.5 30.0

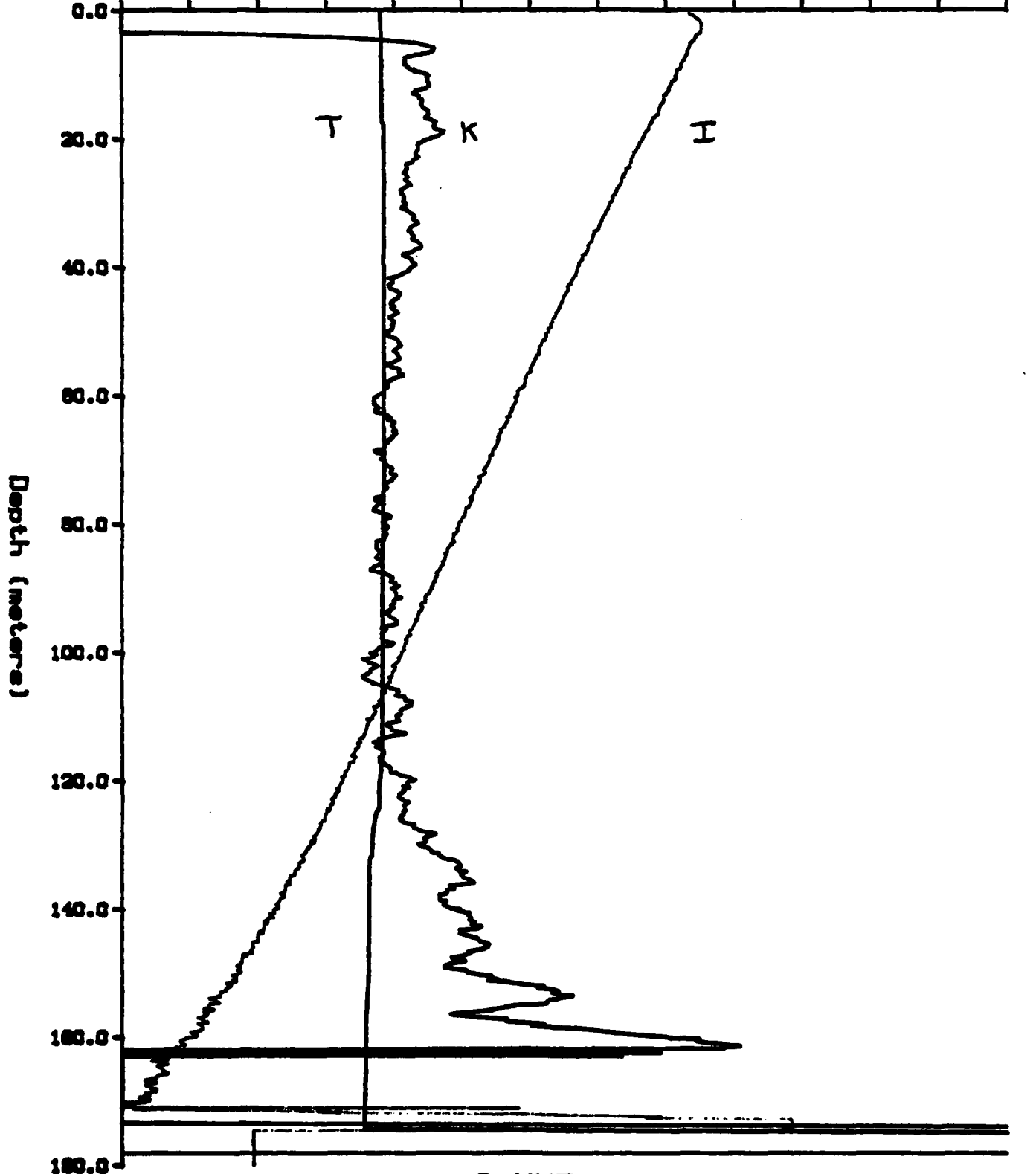


DATE: 1/2/90
 FILE: 8.TIK

#8 XKT

K 1/m
0.00 0.01 0.02 0.03 0.04 0.05 0.06 0.07 0.08 0.09 0.10
Irradiance (Log I)
1.0 2.0 3.0 4.0 5.0 6.0 7.0 8.0 9.0 10.0

Temp. C
-2.5 0.0 2.5 5.0 7.5 10.0 12.5 15.0 17.5 20.0 22.5 25.0 27.5 30.0

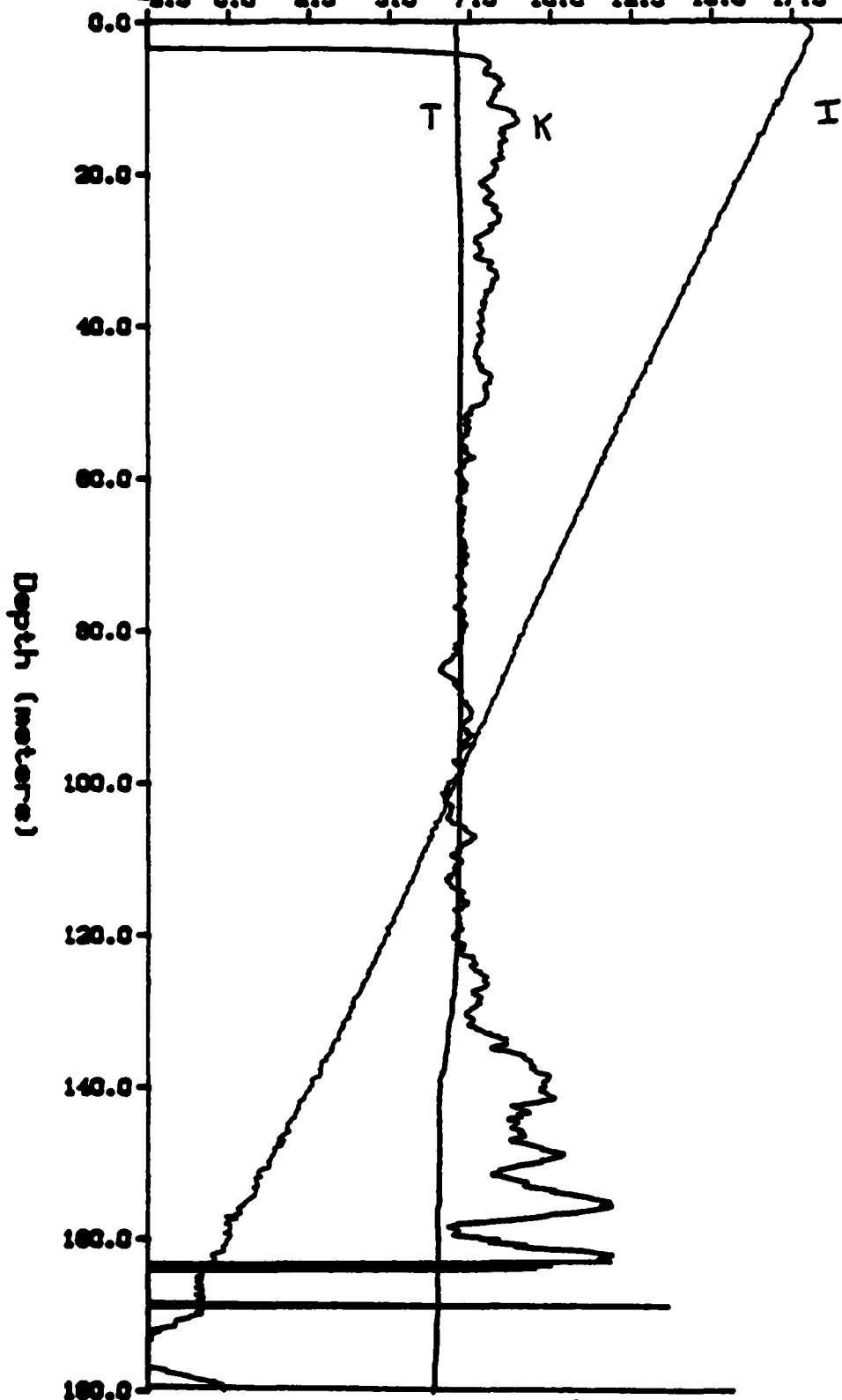


DATE: 1/2/90
FILE: 9.TIK

9 XKT

K 1/m
0.00 0.01 0.02 0.03 0.04 0.05 0.06 0.07 0.08 0.09 0.10
Irradiance (log I)
1.0 2.0 3.0 4.0 5.0 6.0 7.0 8.0 9.0 10.0

Temp. C
-2.5 0.0 2.5 5.0 7.5 10.0 12.5 15.0 17.5 20.0 22.5 25.0 27.5 30.0



DATE: 1/2/80
FILE: 10.TIK

#10 XKT